[Title of the invention]

METHOD OF MANUFACTURING NB-ALLOYED FERRITIC STELL SHEET

[Claim 1]

A method of manufacturing Nb-alloyed steel sheet, comprising the steps of:

providing steel material consisting of 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N and the balance being Fe except inevitable impurities;

hot-rolling the steel material;

annealing the hot-rolled steel sheet at a temperature within a range of 650-900 °C for 1-30 hours;

cold-rolling the annealed steel sheet with a reduction ratio of 50-85%;

finish-annealing the cold-rolled steel sheet at a temperature within a range of 800-930 °C for 10 minutes or shorter.

[Claim 2]

A method of manufacturing Nb-alloyed steel sheet, comprising the steps of:

providing steel material consisting of 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N and the balance being Fe except inevitable impurities;

hot-rolling the steel material;

annealing the hot-rolled steel sheet at a temperature within a range of 950-1100 °C for 10 minutes or shorter for re-crystallization;

annealing the hot-rolled steel sheet at a temperature within a range of 650-900 °C for 1-30 hours;

cold-rolling the annealed steel sheet with a reduction ratio of 50-85%;

finish-annealing the cold-rolled steel sheet at a temperature within a range of 800-930 °C for 10 minutes or shorter.

[Claim 3]

A method of manufacturing Nb-alloyed steel sheet, comprising the steps of:

providing steel material consisting of 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N and the balance being Fe except inevitable impurities;

hot-rolling the steel material;

annealing the hot-rolled steel sheet at a temperature within a range of 650-900 °C for 1-30 hours;

annealing the hot-rolled steel sheet at a temperature within a range of 800-970 °C for 10 minutes or shorter for re-crystallization;

cold-rolling the annealed steel sheet with a reduction ratio of 50-85%;

finish-annealing the cold-rolled steel sheet at a temperature within a range of 800-930 °C for 10 minutes or shorter.

[Claim 4]

The method of manufacturing Nb-alloyed steel sheet according to either one of Claims 1-3, wherein the steel material contains 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N and one or more selected from the group consisting of 0.03-3.0 wt. % of Mo, 0.03-1.0 wt. % of Co, 0.03-1.0 wt. % of Cu, 6.0 wt. % or less of Al and 0.005-0.1 wt. % of REM.

[Claim 5]

The method of manufacturing Nb-alloyed steel sheet according to either one of Claims 1-3, wherein the steel material contains 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N and one or more selected from the group consisting of 0.03-0.2 wt. % of Ti, 0.03-0.2 wt. % of Zr and 0.03-0.2 wt. % of V.

[Claim 6]

The method of manufacturing Nb-alloyed steel sheet according to either

one of Claims 1-3, wherein the steel material contains 0.03 wt. % or less of C, 2.0 wt. % or less of Si, 2.0 wt. % or less of Mn, 0.1 wt. % or less of P, 0.03 wt. % or less of S, 4-30 wt.% of Cr, 0.1-1.0 wt. % of Nb, 0.03 wt. % or less of N, one or more selected from the group consisting of 0.03-3.0 wt. % of Mo, 0.03-1.0 wt. % of Co, 0.03-1.0 wt. % of Cu, 6.0 wt. % or less of Al and 0.005-0.1 wt. % of REM and one or more selected from the group consisting of 0.03-0.2 wt. % of Ti, 0.03-0.2 wt. % of Zr and 0.03-0.2 wt. % of V.

[0006]

An object of the invention is to provide a manufacturing process capable of cheaply manufacturing Nb-alloyed ferritic steel sheets by lowering a of finish-annealing temperature (lowering a recrystallization temperature) after cold-rolling without degradation of high-temperature strength and corrosion resistance from regular level. Another object of the invention is to provide a manufacturing process capable of cheaply manufacturing said steel sheets by lowering a of finish-annealing temperature (lowering a recrystallization temperature) after cold-rolling without degradation of said properties in the case where the rolled ferritic steel material has a single ferrite structure in a temperature zone of hot-rolling.

[0007]

[Means to solve the problems]

The inventors have researched and examined various effects of chemical compositions, hot-rolling, cold-rolling and heat treatment. As a result, the inventors have discovered that a recrystallization temperature falls down by 100°C or more when steel sheets are aged at a proper temperature for a proper time after hot-rolling and that effects of aging are realized by proper control of a cold-rolling rate.

[0014]

[Function]

At first, an example of the invention applied to Nb-alloyed steel is shown in

Figs. 1 and 2. Fig. 1 shows relationship of a finish-annealing temperature (one minute-annealing) with hardness of 14.9 wt. % Cr-0.48 wt. % Nb ferritic steel (steel No. 3 in Table 1) processed by the inventive method (age-annealing a hot-rolled steel sheet of 5 mm in thickness at 800°C for 10 hours, cold-rolling at a reduction ratio of 80%, and then finish-annealing a cold-rolled steel sheet of 2 mm in thickness) or by a conventional method (annealing a hot-rolled steel sheet of 5 mm in thickness at 980°C for 3 minutes, cold-rolling at a reduction ratio of 80%, and then finish-annealing a cold-rolled steel sheet of 2 mm in thickness). It is noted from Fig. 1 that the relationship of a finish-annealing temperature with hardness shifts toward a low temperature, i.e. falling of a recrystallization temperature.

[0015]

Fig. 2 shows effects of a Nb content on a recrystallization temperature of 15 wt. Cr ferritic stainless steel (containing 0.008-0.012 wt. % C, 0.8-0.9 wt. % Si, 0.2-0.3 wt. % Mn, 0.031-0.035 wt. % P, 0.002-0.005 wt. % S and 0.005-0.010 wt. % N) processed by the inventive method (recrystallization-annealing a hot-rolled steel sheet of 5 mm in thickness at 980°C for 1 minute, age-annealing at 800°C for 10 hours, cold-rolling at a reduction ratio of 80%, and then finish-annealing a cold-rolled steel sheet) or by a conventional method (annealing a hot-rolled steel sheet of 5 mm in thickness at 980-1000°C for 3 minutes, cold-rolling at a reduction ratio of 80%, and then finish-annealing a cold-rolled steel sheet of 2 mm in thickness). Herein, the recrystallization temperature is defined as a temperature at which hardness becomes stable from the relationship of an annealing temperature (1 minute annealing) with hardness in Fig. 1.

[0016]

Fig. 2 indicates rising of the recrystallization temperature as an increase of Nb, e.g. 950°C at 0.1 wt. % of Nb and 1000°C at 0.6 wt. % of Nb, in the case of the conventional method. On the other hand in the case of the inventive method, the recrystallization temperature is kept at substantially the same level irrespective

of Nb content, and the recrystallization temperature itself is remarkably lower than that in the conventional method.

[0017]

According to such new process as the invention using aging-treatment, degradation of properties, e.g. workability, high-temperature strength and corrosion resistance, after recrystallization annealing is worried, in comparison with conventionally processed steel sheets. However, ferritic steel sheets, manufactured by the inventive method, have the same properties as those of conventionally processed steel sheets, as noted in the below. Nevertheless a high recrystallization temperature of Nb-alloyed steel has been regarded as unavoidable, the invention fruitfully develops new process for cheaply manufacturing Nb-alloyed ferritic steels due to falling of a recrystallization temperature only after cold-rolling without degradation of properties such as workability, high-temperature strength and corrosion resistance in comparison with conventionally processed steel sheets.

[0018]

The above effects of the invention are fruits originated in the discovery introduced from various experiments over a broad range. The main feature is aging-treatment after hot-rolling and proper control of a cold-rolling ratio. The technical basis on the discovery is not necessarily elucidated but may be explained as follows: an amount of Nb supersaturated in a hot-rolled steel sheet is reduced to a possible lowest level, so as to suppress precipitation of Nb during temperature rising of a cold-rolled steel sheet, resulting in falling of a recrystallization temperature of the cold-rolled steel sheet.